

**NEVADA BUREAU OF LAND MANAGEMENT**  
**ROCK CHARACTERIZATION AND WATER RESOURCES ANALYSIS GUIDANCE**  
**FOR MINING ACTIVITIES**

**INTRODUCTION**

The purpose of this initiative is to provide guidance for the Nevada Bureau of Land Management (BLM) Field Offices and mine operators for rock characterization and development of waste rock management plans, baseline water resources data collection and water resource management plans consistent with 43 CFR 3809.401(b)(2) and 3809.401(c)(1). The goal of this initiative is to improve efficiency and defensibility of the BLM's National Environmental Policy Act (NEPA) documents and Plan approvals, and to improve coordination and efficiencies with the State's permitting processes. In addition, the intent is to expedite the NEPA and Plan of Operations approval processes by developing documents that have been thoroughly analyzed consistent with the BLM and State regulations, policies and Best Management Practices.

The scope of the guidance is to: 1) provide for proper characterization and handling of mined rock to limit its potential to generate acid or liberate other constituents, primarily metals, into the environment and, 2) provide recognized methods to evaluate baseline water resources data and analysis of the potential impacts mining and waste rock management may have for the life-of-mine and long term closure on the hydrologic resources.

The guidance includes references for standardized and, where applicable, certified sampling protocols, analytical methods, and Quality Assurance/Quality Control (QA/QC) procedures for testing laboratories, operators, and regulators to ensure consistent and defensible analysis and results.

It should be noted that whenever possible, the proponent should provide site-specific sampling and testing analysis, meeting agency specifications, for characterization in support of modeling.

**CHECKLIST**

The checklist is all inclusive for characterization of rock and water resources. If certain sections do not apply, such as "Pit Lakes", then the proponent needs to provide the appropriate documentation as to why a pit lake will not form within that section of the report. If there is any indication of potential mine operation/water resource conflicts, specific water resource data collection, testing and modeling efforts should be evaluated by the BLM, in coordination with the State and the mining company.

**ROCK CHARACTERIZATION:**

- I. Materials Characterization
  - 1. Waste rock
  - 2. Ore
    - a. Mill grade
    - b. Spent heap leach material

3. Tailings
4. Pit wall and floor rock
5. Pit backfill rock (dry/wet scenarios)
6. Cap/cover materials (identified site specific sources)

## II. Statistical Approach to Characterization (define statistical adequacy)

1. Sample selection
2. Number of samples
3. Quantity of material
4. Review by BLM/NDEP

## III. Characterization Procedures

1. Sample selection (QA/QC with BLM and NDEP)
2. Identify by rock type/final disposition (ore, waste, pit wall, pit floor, backfill, etc)
3. Record locations (three dimensional)
4. Mineralogical analyses
  - a. XRD
  - b. XRF (could include use of portable field units)
  - c. Petrology
  - d. Petrography (incident light, transmitted light)
  - e. SEM/EDX/NIR/MLA
  - f. Other (with agency approval)
5. Static testing - (required for ore, waste rock and tailings)
  - a. ABA – (“NDEP” Modified Sobek Procedure, including Hot Water Leach – See NDEP/BMRR interim guidance)
  - b. Net acid/alkaline production (AP, NP, NNP)
  - c. MWMP (ASTM E-2242-02) – (includes analysis and report on any metal mobility, attenuation and accumulation potential)
  - d. NCV – use of analysis to be determined by BLM and NDEP to supplement above analyses
  - e. Other (with agency approval)
    1. Paste pH
    2. Net Acid Generation
6. Kinetic testing (required for ore, waste rock and tailings but not for metallurgical ore recovery)
  - a. Humidity cell/column leach
    1. Testing protocols (ASTM D5744-07)  
Protocol calls for weekly cycles composed of three days of dry air (<10% RH) and three days of water-saturated air (~95% RH) pumped up through the sample, followed by a leach with water on Day 7.
    2. Although a test duration as short as 20 weeks may be suitable for some samples, more recent research indicates that test durations well beyond 20 weeks may be required depending on the objectives of the test and the test results. Identified test protocols contain specific criteria to determine when tests may end. **However, the agencies must be consulted prior to terminating the tests. Regardless of the data, 20 weeks is the absolute minimum test period.**

- b. NDEP/BMRR Profile II with total recoverable metals – unfiltered, preserved with HNO<sub>3</sub>
- c. BAPP test- supplemental testing as necessary – to be determined by the agencies

#### IV. Cap/Cover Geotechnical Protocols (may include waste rock, spent leach, etc)

- 1. Grain size
- 2. Atterburg limits
- 3. Initial moisture content
- 4. Dry bulk density
- 5. Calculated porosity
- 6. Constant head analyses for saturated hydraulic conductivity test
- 7. Hanging column
- 8. Pressure plate
- 9. Unsaturated hydraulic conductivity
- 10. Proctor compaction

#### V. Infiltration Modeling

- 1. Heap Leach Draindown Estimation (modeling required)
  - a. Saturated volumetric moisture content
  - b. Residual volumetric moisture content
  - c. Saturated hydraulic conductivity
  - d. Porosity
  - e. Grain size distribution
- 2. Tailings Impoundment Draindown Estimation (modeling required)
  - a. Saturated volumetric moisture content
  - b. Residual volumetric moisture content
  - c. Saturated hydraulic conductivity
  - d. Porosity
  - e. Grain size distribution
- 3. Cap/cover materials (modeling required)
  - a. Saturated volumetric moisture content
  - b. Residual volumetric moisture content
  - c. Saturated hydraulic conductivity
  - d. Porosity
  - e. Grain size distribution

#### VI. Waste Rock Management Plan

- 1. Work plan history with geochemical and geotechnical summaries.
- 2. Operating/post reclamation management of the waste rock dumps (WRDs)
- 3. Describe mining sequence of rock types/volumes/final disposition (see section III.2 above).
- 4. Describe how potentially acid generating (PAG) rock will be selectively mined, segregated and managed to preclude exposure to air and water. Need to address metals mobility/accumulation for both PAG and non-PAG materials (see section III.5.c.).

5. For each benign and PAG WRD facility, include a text description for: toe elevation, crest elevation, ultimate height, reclaimed slope, plan dimensions, tonnage capacity and acres. Provide a summary table for volumes by facility for life-of-mine (LOM).
6. Supplement the text with plan and cross sectional drawings showing: plan views and related alluvial/cover stockpile locations, cross sectional views showing operational and post reclamation slopes, grades; toe and crest elevations, existing ground slope and cap thicknesses for LOM.
7. For pit backfill scenarios, include the same text and supporting drawings previously described, describe any amendment requirements. Provide information on the total volume to be backfilled with rock type and its origin, final backfill elevation and rebound ground water elevation.
8. Tailings impoundments, heaps, ore stockpiles, topsoil stockpiles should include the same text and supporting drawings previously described.

#### WATER RESOURCES CHARACTERIZATION:

##### VII. Geology/Hydrogeology

1. Regional geology/stratigraphy/tectonics (maps, cross sections with grids, scales)
2. Areal regional aquifer and ground water conditions (maps, cross sections)
3. Site specific ground water conditions
  - a. Vadose zone
  - b. Perched water table
  - c. Unconfined water table
  - d. Confined water table

##### VIII. Springs/Streams and Well Inventories

1. Location (including UTM coordinates)
2. Flow/Production
  - a. Perennial springs and streams (include historical flows)
  - b. Intermittent springs and streams (include historical flows)
  - c. Well production (include average/peak or other baseline data)
3. Quality (chemistry)
  - a. NDEP/BMRR Profile (Profile I for ground water, Total Metals for springs/streams/seeps and pit lakes (no filtering of samples))
4. Temperature
5. Well drilling log or geologic log
6. Water rights
7. Jurisdictional waters
8. Habitat types, areal distributions and number of acres (include maps)

##### IX. Hydrologic System

1. Meteorology (use on-site meteorological station data)

- a. Ambient Temperature (min/max), Relative Humidity, Wind Speed (max gust/hr) & Wind Direction, Total Precipitation, Solar Radiation; at a minimum with a data logger.
  - 2. Recharge
    - a. Type
    - b. Distribution
  - 3. Discharge
    - a. Type
    - b. Distribution
  - 4. Potentiometric surface or water table
  - 5. Groundwater flow
    - a. Gradient and flow direction
    - b. Velocity
  - 6. Hydraulic boundary conditions/hydrologic divides
    - a. Type
    - b. Distribution
- X. Hydrologic Budget (summary of Section IX.)
- XI. Conceptual Groundwater Model
- 1. Ground and surface water systems (based on site specific field data)
  - 2. Project hydrogeologic setting (relative to regional hydrology)
- XII. Pit Lakes
- 1. Modeling based on chemistry from sections I.1 and I.2, hydrology from sections VII, VIII and IX (above). Also see IM NV–2008-034 in the References section.
- XIII. Geothermal Waters
- 1. Address any potential resource issues
- XIV. Other (site specific)

## **REFERENCES/LINKS/REGULATIONS/PROTOCOLS**

The following sources may be useful in rock characterization, development of waste rock management plans, baseline water resources data collection and water management plans. Note that the BLM does not require specific models as part of the Plan submittal, but may use specific models to verify modeling results. Modeling of water resources must be approved by the agencies. Certified labs, testing procedures and protocols are required, as appropriate. The proponent should coordinate with the BLM and State representatives prior to sample suite selection and conducting characterization testing. In addition, the proponent must have agencies written concurrence that materials testing are appropriate, representative and stabilized prior to completing testing at analytical labs.

### Analytical Profiles:

NDEP/BMRR Profile I – reference NDEP Form 0190.

NDEP/BMRR Profile II - reference NDEP Form 0090.

NDEP/BMRR Water Quality Sampling Protocol for Metals (1998) – reference NDEP Form 0090, use for unfiltered sampling for total recoverable metals.

“NDEP” Modified Sobek Procedure – see NDEP/BMRR interim guidance. Modified Sobek Procedure, including Hot Water Leach – MSU – Reclamation Research Unit (EPA-600/2-78-054).

#### ASTM Protocols:

Note: ASTM standards are copywrited. As such, the proponent or their contractors are responsible for any fees.

<http://www.astm.org/>

ASTM D5744-07 Standard Test Method for Laboratory Weathering of Solid Materials Using a Humidity Cell.

ASTM E1915-07a Standard Test Methods for Analysis of Metal bearing Ores and Related Materials by Combustion Infrared-Absorption Spectrometry (NCV).

ASTM E2242-02 Standard Test Method for Column Percolation Extraction of Mine Rock by the Meteoric Water Mobility Procedure.

Modified Sobek Procedure - incl. Hot Water Leach- MSU - Reclamation Research Unit.

#### BLM Instruction Memorandums:

IM NV-2008-032 Nevada Bureau of Land Management’s Water Resource Data and Analysis Policy for Mining Activities

IM NV-2008-033 Nevada Bureau of Land Management Reclamation/Closure Policy for Hardrock Mining Activities

IM NV-2008-034 Ecological Risk Assessment Guidelines for Open Pit Mine Lakes in Nevada

IM NV-2008-035 Groundwater Modeling Guidance for Mining Activities

#### Memorandums of Understanding:

NV EPA MOU 2008 Memorandum of Understanding for Mining Environmental Impact Statements within the State of Nevada between the Bureau of Land Management and the U.S. Environmental Protection Agency

NV MOU 11.20.08 Memorandum of Understanding for Mining and Mineral Related Activities within the State of Nevada Among Nevada Dept. of Conservation, Division of Environmental Protection and US Dept of Agriculture –Forest Service Humboldt –Toiyabe National Forest and Inyo National Forest and the Nevada BLM

BLM guidance, Reclamation Permit guidance, WPCP guidance:

BLM guidance:

<http://www.blm.gov/nv/st/en/prog/minerals/mining.html>

POO Format 2009 tsm 1.9.09 Voluntary 3809 Plan of Operations Outline/Format

Reclamation Permit guidance:

<http://ndep.nv.gov/bmrr/recapp.htm#docs>

WPCP guidance:

<http://ndep.nv.gov/bmrr/regapp.htm>

Regulatory Authorities:

43 CFR 3809 – BLM Mining Regulations

State of Nevada NAC 445 regulations – Water Pollution Control Permit

State of Nevada NAC 519 regulations – Reclamation Permit

Statistical references:

U.S. EPA 2006, Guidance on Choosing a Sample Design for Environmental Data Collection, December 2002.

U.S. EPA 2006, Data Quality Assessment: Statistical Methods for Practitioners, EPA QA/G-9S, EPA/240/B-06/003.

U.S. EPA 530-D-02-02, August 2002, RCRA Waste Sampling Technical Guidance, Office of Solid Waste.

General References:

Category/Document Title	Number/Date
<a href="#">Rock Characterization, Test Methods, Modeling, and Concept Discussions</a>	
“Glossary of Terms Used in Metals Leaching and Acid Rock Drainage Work”	Anonymous
The International Network for Acid Prevention (INAP), Global Acid Rock Drainage Guide (GARD Guide) <a href="http://www.gardguide.com/">http://www.gardguide.com/</a>	2009
“Static-Test Methods Most Commonly Used to Predict Acid Mine Drainage: Practical Guidelines for Use and Interpretation”, White III, Lapakko, Cox	1999
“EPA and Hardrock Mining: A Source Book for Industry in the Northwest and Alaska; Appendix ‘C’, Characterization of Ore, Waste Rock, and Tailings”	January 2003

Category/Document Title	Number/Date
“Standardization of Mine Waste Characterization Methods by ADTI-MMS”, Charles Bucknam, William White III, Kim Lapakko	June 2009
“Static and Kinetic Tests Commonly Used for Prediction of Acid Mine Drainage from Metallic Sulfide-Bearing Waste Rock: Methods, Costs & Confidence Limits”, White III and Froisland	October 1991
“Field and Laboratory Methods Applicable to Overburden and Minesoils”, Andrew Sobek, William Schuller, John Freeman, Richard Smith (SOBEK Excerpt EPA-600/2-78-054)	March 1978
“Solid Phase Characterization in Conjunction with Dissolution Experiments for Prediction of Drainage Quality”, Lapakko	June 1990
“Effects of Protocol Variables and Sample Mineralogy on Static-Test NP”, W.W.White III, K.A.Lapakko, R.L.Cox	April 1997
“Kinetic Testing 1. Effects of Protocol Variable on Rates of Weathering”, Frostad, Klein, Lawrence, ICARD 2000	2000
“Acid-Base Accounting to Predict Post-Mining Drainage Quality on Surface Mines”, Skousen, Simmons, McDonald, Ziemkiewicz	2002
“A Simple Accelerated Rock Weathering Method to Predict Acid Generation Kinetics”, Kargbo and He	July 2004
“Acid Base Accounting (ABA) Test Procedures”, Chris Mills Editor	January 2005
“Humidity Cells: How Long? How Many?”, Kevin A. Morin, Nora M. Hutt	13-15/ix/1999
“Developments in Humidity-Cell Tests and Their Application”, Kim A. Lapakko	2003
“Pyrite Oxidation Rates from Humidity Cell Testing of Greenstone Rock”, Lapakko and Antonson	March 2006
SGS Technical Memorandum “Continuation/Decommissioning of Osisko Humidity Cell Tests, Malartic Project”, Chateauneuf	October 2008
“University of Utah Acid Mine Drainage Research Group, Humidity Cell Model Version 4.01”, Lin, Guard, Dumett, Trujillo	2000??
“Advances in Acid Drainage Prediction Using the Net Acid Generation (NAG) Test”, Miller, Robertson, Donohue	1998?
“Use of the Net Acid Generation pH Test for Assessing Risk of Acid Generation”, William M. Schafer	2000
“A Comparison of Kinetic NAG Tests with Static and Humidity Cell Tests for the Prediction of ARD”, Sapsford, Bowell, Dey, Williams, Williams	2000??
“Evaluation of the Net Acid Generation (NAG) Test for Assessing the Acid Generating Capacity of Sulfide Minerals”, W. Stewart, et al	12-18/vii/2003
“Violation of Common ABA Prediction Rules by Molybdenum-Related Minesites in British Columbia, Canada”, Kevin . Morin, Nora M. Hutt, et al	June-July 2001
“Release of Acid from Hydrothermal Quartz-Carbonate Hosted Gold-Mine Tailings”, Lapakko and Wessels	June 1995
“Progress of BLM-Funded Acid Mine Drainage Research”, White III, Lapakko, Trujillo	2002
<i>Water Resource Characterization, Test Methods, Modeling, and Concept Discussions</i>	
“Water Quality Sampling for Metals” (NDEP Guidance Document)	December 1998
“Nevada Bureau of Land Management’s Water Resource Data and Analysis Policy [Guide] for Mining Activities”, BLM, State Director, Nevada, Instruction Memorandum No. NV-2008-032	15 April 2008
“Groundwater Modeling Guidance for Mining Activities” with “Table of References”, BLM, State Director, Nevada, Instruction Memorandum No. NV-2008-035	21 April 2008
<i>Rock Characterization Internet Case Studies</i>	
“Neutralization Potential: What is it and Why is it Important for Drainage Chemistry?”	November 1997
“Upside-Down Oxidation Profile in Sulfide-Bearing Tailings”	May 1998
“Contribution of Bacteria to Sulfide-Mineral Reaction Rates in Natural Environments”	November 1998
“Comparison of NAG Results to ABA Results for the Prediction of Acidic Drainage”	January 1999
“Prediction of Minesite-Drainage Chemistry Using the “Wheel” Approach”	November 1999
“Why Include Ore Samples in the Prediction of Minesite-Drainage Chemistry; When	August 2004

Category/Document Title	Number/Date
Ore is not Waste?"	
"Should a Humidity-Cell Sample Be Gently Agitated During Testing?", Morin and Hutt	2006
"Errors from Sampling Humidity Cells Every Second Cycle", Morin and Hutt	2007
<a href="#">ASTM International Test Methods</a>	
Standard Guide for Reporting Results of Analysis of Water	D 596-01
Test Method for Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lbf/ft <sup>3</sup> (600 kN-m/m <sup>3</sup> )) [Standard Proctor]	D 698-91
Standard Terminology Relating to Water	D 1129-04
Test Method for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lbf/ft <sup>3</sup> (2,700 kN-m/m <sup>3</sup> )) [Modified Proctor]	D 1557-91
Standard Classification of Soils for Engineering Purposes (Unified Soil Classification System)	D 2487-93
Standard Practice for Description and Identification of Soils (Visual-Manual Procedure)	D 2488-93
Standard Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils	D 4318-93
Standard Guide for Sampling Ground-Water Monitoring Wells	D 4448-01
Standard Test Methods for Screening pH in Waste	D 4980-89
Standard Test Method for Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter	D 5084-90
Standard Practice for Design and Installation of Ground Water Monitoring Wells in Aquifers	D 5092-90
Standard Guide for Comparison of Field Methods for Determining Hydraulic Conductivity in the Vadose Zone	D 5126-90
Standard Test Method for Accelerated Weathering of Solid Materials Using a Modified Humidity Cell	D 5744-07
"Modification of the ASTM 5744-96 Kinetic Test", Lapakko and White III	2000
"Preliminary Indications of Repeatability and Reproducibility of the ASTM 5744-96 Kinetic Test for Drainage pH and Sulfate Release Rate", White III and Lapakko	2000
Standard Guide for Planning and Preparing for a Groundwater Sampling Event	D 5903-96
Standard Guide for Documenting a Ground-Water Sampling Event	D 6089-97
Standard Guide for Field Preservation of Ground-Water Samples	D 6517-00
Standard Guide for Collection of Water Temperature, Dissolved-Oxygen Concentrations, Specific Electrical Conductance, and pH Data from Open Channels	D 6764-02
Standard Test Methods for Analysis of Metal Bearing Ores and Related Materials by Combustion Infrared-Absorption Spectrometry	E 1915-07a
Standard Test Method for Column Percolation Extraction of Mine Rock by the Meteoric Water Mobility Procedure	E 2242-02

## ACRONYMS/TERMINOLOGY

The following are acronyms contained within this document.

ABA – Acid Base Accounting

AP – Acid Potential

ASTM – American Society for Testing and Materials

BAPP – Biological Acid Production Potential

BMRR – Bureau of Mining Regulation and Reclamation

BLM – Bureau of Land Management

EDX – Energy Dispersion X-ray spectroscopy

HLDE – Heap Leach Draindown Estimator (Excel spreadsheet)

LOM – Life of Mine

MWMP – Meteoric Water Mobility Procedure

NDEP – Nevada Division of Environmental Protection

NEPA – National Environmental Policy Act

NIR – Near Infra-Red

NP – Neutralizing Potential

NNP – Net Neutralizing Potential

NCV – Net Carbonate Value

PAG – Potentially Acid Generating (in reference to rock)

QA/QC – Quality Assurance/Quality Control

SEM – Scanning Electron Microscope

WPCP – Water Pollution Control Permit

WRD – Waste Rock Dump

XRD – X-ray Diffraction

XRF – X-ray Fluorescence